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Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles

American Welding Society

Keywords — Arc welding processes, crossings, engine burns, flash butt welding, frogs, oxyfuel welding, procedure qualification, railroad safety, railroad welding, rails, switch points, thermite welding, track, welder qualification

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Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles

Prepared by
AWS Committee on Railroad Welding

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This document recommends minimum standards for the maintenance welding of rails and related rail components used by rail vehicles. Repair procedures for rails and austenitic manganese steel components are covered. Thermite welding and electric flash butt welding guidelines are discussed. Procedure qualification, welder qualification, and general welding safety procedures are addressed.

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Foreword

(This Foreword is not a part of ANSI/AWS D15.2-94, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is included for information purposes only.)

This recommended practice establishes standards for the joining, repair, maintenance and inspection of rail welds and the welding of related rail components. It was developed and is maintained by the Subcommittee on Track Welding within the AWS Committee on Railroad Welding.

The welding of rails and related rail components for use by rail vehicles is vital to the safe and economical operation of American railroads. This subcommittee has endeavored to develop these recommended practices to serve as a guideline for the railroad and related industries in the establishment of track welding specifications. The subcommittee is made up of individuals from all segments of the railroad industry, both users and suppliers, and representatives of both the Association of American Railroads and the American Railway Engineering Association.

The purpose of this document is to provide a single comprehensive source of information that will be used throughout the railroad industry. It should act as a guideline towards improving welding quality through the economical joining and repair of rail and rail components.

Comments and suggestions for the development of this standard should be addressed to: Managing Director, Technical Services Division, American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126.

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society. A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

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Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles

1. Scope

This document recommends standards for the joining, repair, maintenance, inspection of rail welds, and related rail components. For the purposes of this document, rails include railroad rails, crane rails, guard rails, electrical contact rails, girder rails, and retarder rails. Classification of rails is based on the American Railway Engineering Association (AREA) specifications governing the manufacture of rails.

Related rail components include rail crossings and turnouts which further include switch points, stock rails, switch point guards, spacer blocks, connecting rods, switch rods, plates, frogs, and frog components.

The use of track components reconditioned by welding is a decision of the rail owner outside the scope of this document. This document does not include road bed maintenance except where it affects the expected life of the repair. Safety precautions shall conform to the latest edition of ANSI/ASC Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society. (See also Annex E, *Safe Practices.*)

2. Rail, Rail Components Manufactured from Rail, and Their Repair

FOR OPTIMUM PERFORMANCE IDENTIFICATION OF THE TRACK MATERIAL TO BE WELDED IS ESSENTIAL FOR THE SELECTION OF THE WELDING PROCEDURE.

2.1 Specific Items. These recommendations apply to, but are not limited to, the items listed in the Scope.

2.2 Welding Processes. Welding processes include shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), flash welding (FW) (electric flash butt welding), thermite welding (TW), and oxyfuel gas welding (OFW). See Annex A and Volume 2, Eighth Edition, *Welding Handbook* for details.

2.3 Railroad Rail Welding

2.3.1 Railroad Rail Grades

2.3.1.1 Carbon steel rail having a minimum hardness of 240 BHN.

2.3.1.2 Premium steel rail has a nominal hardness exceeding 341 BHN. This hardness may be the result of alloy composition (nonheat treated), full heat treatment, selective hardening of the rail head, or a combination of these processes. Heat treated rail and other variations may require special welding procedures as recommended by the rail manufacturer or filler metal producer, or both.

2.3.1.3 Electrical contact rails are low-carbon steel rails without hardness requirements.

2.3.2 Procedure Requirements Common to Both Carbon Steel and Premium Steel Rail

2.3.2.1 Preheating the weld areas to 800–1000°F (427–540°C), as measured immediately before welding, is recommended.

2.3.2.2 Interpass temperature should be within the same range as the preheat temperature.

2.3.2.3 Filler metal should provide weld metal having a nominal surface hardness compatible with the existing base metal.

2.3.2.4 Postweld heat treatment is not required unless dictated by past experience or by approved railroad welding procedures.

2.3.3 Procedure Requirements Specific for Premium Steel Rail

2.3.3.1 A preheating temperature of 800–1000°F (427–540°C) is recommended for premium steel rail.

2.3.3.2 Cooling rate shall be controlled to minimize undesirable metallurgical transformations leading to brittle structures or poor wear resistance. The required cooling rate depends on rail size and chemical composition, filler metal, and ambient welding temperature.

2.3.3.3 In all cases, heating rates and cooling rates shall be gradual.

2.4 Repair of Battered Rail Ends and Wheel Burns (Carbon Steel or Premium Steel Rail)

2.4.1 Carbon steel or premium steel rail may be repaired using a process selected from 2.2 and Table 1.

2.4.2 Rail Preparation

2.4.2.1 Visually inspect the rail to determine repairability in accordance with this document and the rail owner's policy.

2.4.2.2 Defective material should be removed to sound base metal. Soundness may be checked using dye penetrant testing, or equivalent.

Table 1
Allowable Processes for Carbon and Alloy Steel Rail Components

Component Material	Acceptable Processes
Carbon steel	Shielded metal arc welding (SMAW) Gas metal arc welding (GMAW) Flux cored arc welding (FCAW) Oxyfuel gas welding (OFW) Flash welding (FW) (Electric Flash Butt Welding) Thermite welding (TW)
Premium steel	Shielded metal arc welding (SMAW) Gas metal arc welding (GMAW) Flux cored arc welding (FCAW) Flash welding (FW) (Electric Flash Butt Welding) Thermite welding (TW)

2.4.3 Welding Procedure

2.4.3.1 As outlined in 2.3.2 or 2.3.3, preheat the repair area plus 4–6 in. (100–150 mm) longitudinally beyond the weld area in both directions.

2.4.3.2 Interpass temperature should be within the same range as the preheat temperature.

2.4.3.3 All the above recommended temperatures are dependent on the base metal composition, the filler metal used, ambient temperature, weather conditions, and the manufacturer's recommendations.

2.4.3.4 Weld beads should be made primarily in the longitudinal direction for proper heat distribution.

2.4.3.5 Diagonal or chevron weld bead patterns are preferred. See Figure 1 for typical chevron pattern.

2.4.3.6 Provisions must be made to prevent permanent distortion of the weld area.

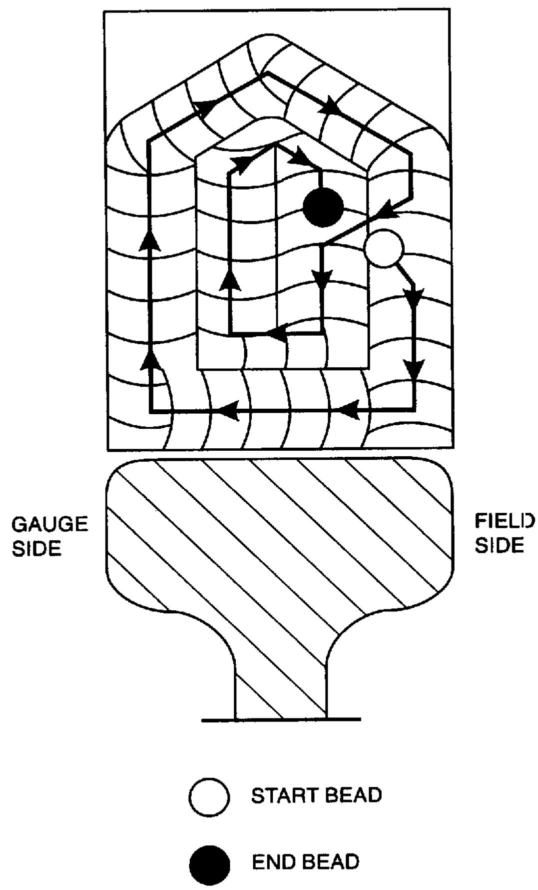


Figure 1—Typical Weld Pattern for Rail End Repair

2.4.3.7 All weld craters shall be filled.

2.4.3.8 Arc strikes shall not be permitted outside the preheated repair area. Accidental arc strikes outside the repair area shall be repaired in accordance with the provisions of this section.

2.4.4 Finish Grinding

2.4.4.1 Welds should be finish ground according to approved procedures the same day the rail is welded.

2.4.4.2 Finished surface of the weld should be smooth and uniform to match the existing rail contour.

2.5 Repair of Rail-Type Switch Points and Switch Point Protectors

2.5.1 Repair of austenitic manganese switch points is not recommended.

2.5.2 Carbon steel and premium steel rail components may be welded by the processes shown in Table 1.

2.5.3 Visually inspect the switch point or switch point protector to determine the repairability in accordance with this document and the rail owner's policy.

2.5.4 Defective material should be removed to sound base metal. Soundness may be determined by dye penetrant or magnetic particle testing.

2.5.5 Temperature control is extremely critical because of variations in thickness and the need to minimize distortion.

2.5.6 Switch Point Repair Procedure

2.5.6.1 Welding the switch point against a stock rail is not recommended because of the possibility of arc strikes on the rail. Copper plates or graphite (carbon) backing blocks should be used.

2.5.6.2 Switch point must be protected from traffic movement during welding, cooling, and finish grinding.

2.5.6.3 Hammer shaping of repaired carbon steel rail switch points at temperatures below 1800°F (980°C) is not recommended. Hammer shaping of alloy or heat-treated switch points is not recommended.

2.5.7 **Preheat Procedure.** Preheat the switchpoint assembly in the weld areas, as measured immediately before welding, to 800–1000°F (427–540°C) unless otherwise recommended by the rail owner. If there are temperature differences between the recommendations of the rail owner and this document, the rail owner's recommendation shall prevail.

2.5.8 Interpass temperature shall be in the same range as the preheat temperature.

2.5.9 Application of Filler Metal

2.5.9.1 Longitudinal lineal stringer beads are recommended for carbon steel rail. Slight oscillation resulting in slower lineal travel speed and increased lineal heat input may be beneficial for premium steel rails. Weld bead pattern shall be in accordance with the operating procedures of the specific railroad.

2.5.9.2 All welds shall be finished to the approved contour.

2.5.9.3 Arc strikes shall not be permitted outside the preheated weld repair area. Accidental arc strikes outside the repair area shall be repaired after review by the Engineer in charge.

2.6 Frogs, Crossings and Other Components Made from Rail Steel. Practices outlined in 2.4 are applicable.

2.7 Miscellaneous Carbon Steel and Low Alloy Steel Components. Practices outlined in 2.4 should be applicable.

3. Repair or Fabrication of Components Manufactured from Austenitic Manganese Steel

3.1 Metallurgical Background. For a general discussion of the welding of austenitic manganese steel see Annex B.

3.2 Components. Austenitic manganese steel components include but are not limited to frogs, crossings, switch point guards, casting inserts, and bridge track components.

If composition of the component is in doubt, a hand magnet should be used for identification purposes. An austenitic manganese steel component will be nonmagnetic, or at the most, have a slightly magnetic skin. The carbon steel or low alloy steel component will be strongly magnetic.

3.3 Welding Processes

3.3.1 Manual welding processes are restricted to shielded metal arc welding with bare or covered electrodes.

3.3.2 Semiautomatic and automatic welding processes refer to flux cored arc welding.

3.4 Filler Metals

3.4.1 Austenitic manganese steel shall not be surfaced nor joined using carbon steel or low alloy steel welding electrodes or welding wires. The resultant weld metal may fail.

3.4.2 Austenitic Manganese Welding Electrodes

3.4.2.1 ANSI/AWS A5.13, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding,* and ANSI/AWS A5.21, *Specification for Surfacing Welding Rods and Electrodes,* detail several basic compositions.

3.4.2.2 ANSI/AWS A5.13 and ANSI/A5.21 reflect the variety of modifications of the basic austenitic manganese composition currently available. The electrodes generally deposit undiluted weld metal with a manganese content in excess of 14 percent plus smaller additions, alone or in combination, of nickel, molybdenum, chromium, or vanadium.

3.4.2.3 The range of properties developed by these electrodes enables the user to select the combination best suited for the particular application. For example, an overlay with a relatively high yield strength might be used to build up the running surface of frogs whereas an alloy with a yield strength more closely matching that of the base metal might be used to repair a deep crack.

3.4.3 Special chromium-nickel-iron and chromium-manganese-nickel-iron austenitic electrodes also are used to weld austenitic manganese base metal.

3.5 Preparation for Welding

3.5.1 Austenitic Manganese Steel Castings

3.5.1.1 Grease, rust, and dirt should be removed from the surfaces by appropriate means.

3.5.1.2 The entire casting should be inspected for cracks and other defects. Dye penetrant testing may be used to locate and define the cracks.

3.5.1.3 Cracks should be removed as completely as practical by grinding or air arc gouging. The latter is the preferred process. The use of a cutting torch is not recommended. Air arc gouging procedures should be as follows:

(1) Locate the end of the crack using a shallow cut.

(2) Make a deeper cut moving from the end of the crack towards the edge of the casting.

(3) If the crack does not extend to the edge, air arc gouging should proceed from the ends towards the middle of the crack.

(4) Gouging should be continuous utilizing straight rapid cuts.

(5) Metal and oxides should be eliminated from the groove.

(6) Groove should be kept just wide enough to permit electrode manipulation during welding.

(7) Base metal temperature should not exceed 500°F (260°C) adjacent to the area being gouged.

3.5.1.4 Worn areas should be located and marked using a straight edge or template.

3.5.1.5 Work hardened (plastically deformed) metal should be removed.

3.5.1.6 Sharp edges along flangeway surfaces should be rounded slightly.

3.5.2 For Castings to be Welded in Track. Track conditions that may have contributed to the damaged or worn casting shall be corrected prior to welding.

3.5.3 For Castings to be Shop Repaired

3.5.3.1 Rail-bound frogs should be stripped before examination for cracks.

3.5.3.2 Distortion control procedures such as pre- or postweld bending should be considered by the repair shop.

3.6 Welding Recommendations—General

3.6.1 The repair of each worn casting tends to be an individual job not subject to rigid definition. Therefore, the recommendations of this section are of a general nature applicable to a wide variety of applications.

3.6.2 When the casting temperature is below 32°F (0°C), it shall be warmed to approximately 70°F (21°C) before any welding or gouging. To prevent embrittlement of the base metal, interpass temperatures should not exceed 500°F (260°C) maximum at a point 1 in. (25 mm) from the area being welded.

3.6.3 Diameter of covered electrodes for SMAW should not exceed 3/16 in. (4.8 mm).

3.6.4 Diameter of flux cored wire for semiautomatic welding should not exceed 7/64 in. (2.8 mm).

3.6.5 Welding current should be sufficient to ensure adequate penetration and bead tie-in. Excess current should be avoided to prevent heat buildup.

3.6.6 Arc length should be maintained as short as possible while maintaining good arc characteristics.

3.6.7 Weld beads should be slightly crowned and, no more than 5/8 in. (16 mm) in width.

3.6.8 Length of individual weld bead should not exceed approximately 5 in. (250 mm) when welding in track. In the shop where precautions can be taken to minimize distortion and heat buildup, longer welds are permitted.

3.6.9 Heat input into the casting should be monitored frequently. Welding should be discontinued in any area where the casting temperature exceeds 500°F (260°C) measured approximately 1 in. (25 mm) from the weld area.

3.6.10 Skip welding should be used to minimize heat buildup, as shown schematically in Figure 2.

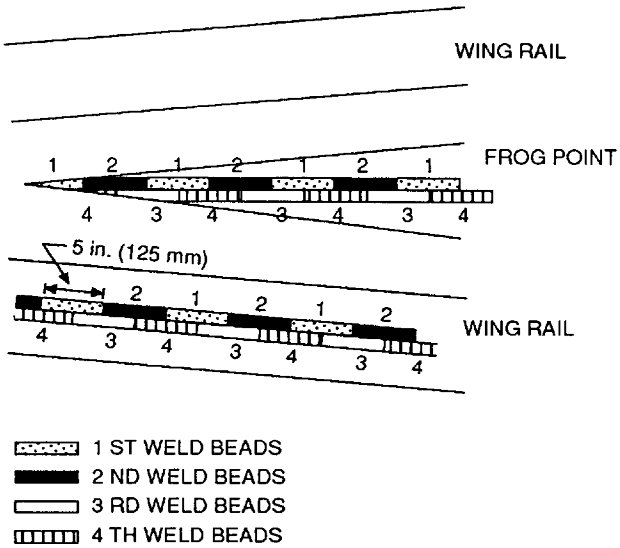


Figure 2—Skip Welding Repair Made in 5 in. (125 mm) Long Increments

3.6.11 Carbon blocks or copper plates may be used in the flangeways to maintain proper contour and minimize finish grinding.

3.6.12 Flangeway beads should be deposited first.

3.6.13 Adjacent beads should have a 35–50 percent overlap.

3.6.14 The direction of successive beads should be reversed to minimize stress buildup.

3.6.15 The end of welds should be staggered to further minimize stress buildup.

3.6.16 Weld beads should not be started or stopped at the edge of the casting.

3.6.17 Welds on frog wings or points should be parallel to the flangeways.

3.6.18 The general procedure for welding frog points is as follows:

3.6.18.1 Welding should start at the lowest point of the repair area gradually building up to the full width of the repair.

3.6.18.2 The arc should be struck about 1/2 in. (13 mm) ahead of where the beads are to begin, dragged to the starting point, and then welded back into the bead before breaking the arc.

3.6.18.3 Craters should be filled by reversing direction and welding back into the bead before breaking the arc.

3.6.19 Successive layers of austenitic manganese or specially modified stainless steel weld metals may be applied to achieve the desired thickness of buildup.

3.6.20 Individual layers of weld metal should be visually examined prior to proceeding with the next layer. Any unacceptable indications should be repaired prior to starting the next layer.

3.6.21 If defect removal requires grinding through the thickness of the casting, a back-up bar, preferably austenitic manganese steel, should be used to provide a base for welding.

3.6.22 If a long deep cavity has to be filled, sections about 5 in. (125 mm) long should be treated as incremental welding repairs as shown in Figure 2.

3.6.22.1 Adjacent 5-in. (125 mm) sections should not be welded sequentially. See Figure 2.

3.6.22.2 Individual layers in 5-in. (125 mm) sections should cascade as shown in Figure 2 to facilitate tie-in of the individual sections.

3.7 Welding Recommendations—Frogs and Crossings in Track

3.7.1 The general recommendations of 3.6 should apply, as applicable.

3.7.2 Safe movement of trains while frogs are being repaired should be the first priority.

3.7.2.1 Cracks and major break-out areas should be repaired prior to the buildup of worn areas.

3.7.2.2 Large areas to be welded should be subdivided into sections in such a way that train movement will not be disrupted.

3.7.2.3 Complete width or long weld repairs should be made sequentially. Typical sequences are shown in Figure 2.

3.7.2.4 The guards of self-guarded frogs should be rebuilt to their original dimension prior to other repairs. Enough time should be allowed between traffic movements to allow complete welding and finish grinding of the raised guard. After the guards have been repaired, the tread portion should be restored.

3.7.2.5 Immediately after completing each bead, peen the bead with the ball end of a two pound ball-peen hammer. The bead should be struck four times per inch of weld using moderate blows that produce an indentation of approximately 0.04 in (1.0 mm). Peening should start at the crater and proceed toward the start of the weld. DO NOT PEEN THE FIRST AND FINAL LAYERS.

4. Recommended Practices for Joining of Rails by Thermite Welding (TW)

Thermite is defined as a mixture of finely divided aluminum and iron oxide. When the aluminum and iron oxide react, the reaction is called a *thermite reaction.* Thermite welding is accomplished with the heat produced by the thermite reaction. Filler metal is obtained from the combination of the iron reaction product and pre-alloyed shot in the mixture.

4.1 General Description. Thermite welding is a welding process that joins rail ends by melting them with superheated liquid metal from a chemical reaction between iron oxide and aluminum. Filler metal is obtained from the liquid metal, Figure A5.

4.1.1 For a general discussion of the process, see Volume 2, Eighth Edition, *Welding Handbook.*

4.1.2 Thermite welding supplies are sold under a number of commercial trade names.

4.2 Application

4.2.1 Application includes, but is not limited to, items listed in the Scope.

4.2.2 The thermite welding process may be utilized to weld both carbon steel rail and low alloy steel premium rail. Special precautions may be necessary when welding alloy steel premium rail.

4.3 Preparation of the Final Gap for Welding

4.3.1 Rail ends should be aligned properly, both laterally and vertically. Rail ends should be secured to prevent movement during the welding process.

4.3.2 The root opening between rails may be oxyfuel gas cut, sawed, or cut with an abrasive disc. Of these, oxyfuel gas cutting is the least desirable.

4.3.2.1 If the final gap is to be prepared by OFC, the rail should be preheated to 700°F (371°C) prior to the oxyfuel gas cut.

4.3.2.2 Care should be exercised to ensure smooth cut surfaces. An end squareness of ±1/16 in. (1.6 mm) both horizontally and vertically is recommended.

4.3.2.3 Ends of oxyfuel gas cut rails should be cleaned thoroughly to remove all residual oxide.

4.3.3 The root opening between the rail end faces may vary depending on the specific commercial process.

4.3.4 Irrespective of the cutting process, at least 6 in. (150 mm) on each side of the gap should be free of the following:

(1) All moisture and foreign substances such as dirt, grease, loose oxide, burns, fins, and metal flow

(2) Copper material from head bonds for at least 2 in. (50 mm) on each side of the weld area.

In addition, a 6 in. (150 mm) hole free zone is recommended.

4.4 Welding Procedure. Welding procedure including preheating techniques, method of ignition, rate of cooling, and mold removal will vary somewhat depending on the instructions of the manufacturer of the specific thermite kit being employed and the type, size and chemistry of the specific rail being welded, as well as the local service conditions.

4.5 Care of Thermite Materials

4.5.1 Molds shall be protected from moisture contamination and freezing during storage. Charges shall be protected from moisture contamination during storage.

4.5.2 Charges and molds shall be protected from moisture contamination during transportation from storage to work site.

4.5.3 Molds and charges shall be used within the shelf-life period recommended by the manufacturer.

4.5.4 Crucibles (reaction chambers) shall be clean and dry at all times.

4.5.5 Crucible, mold, charge, and adjacent rail area shall be protected from moisture.

4.5.6 *DANGER: INTRODUCTION OF MOISTURE TO THE THERMITE WELDING PROCESS MAY CAUSE SERIOUS OR FATAL INJURY.* Molten steel and hot slag can cause serious explosion upon coming into contact with snow, ice, standing water, frozen ballast or soil.

4.5.7 Rail weld geometry shall be checked with a straight edge and taper gauge in accordance with the requirements of *AREA 4-2-6.2* or those selected by the operating authority.

4.5.8 Alignment and Finish Requirements for Wear Surface

4.5.8.1 Alignment tolerance of running surfaces should be within the requirement of the individual railroad.

4.5.8.2 Additional grinding to remove surface defects should be kept to a minimum.

4.5.8.3 If required, grinding of the weld collar should be symmetrical.

4.5.8.4 Radiography is not recommended for inspection of thermite welds. Defects are very difficult to detect and interpret.

4.5.8.5 Visual and ultrasonic examinations of finished welds are recommended.

4.6 Procedure Qualification. Procedure tests performed by the thermite manufacturer may be accepted by the user if individual testing is not feasible.

4.7 Welder Qualification

4.7.1 Prior to qualification, welders should receive training from qualified instructors.

4.7.2 In the absence of established welder qualification tests, the welding supervisor should determine the tests required.

4.7.3 Results of the evaluation of the welder should be made a part of the operator's permanent record.

4.8 Thermite Welding Safety Precautions

4.8.1 Over tightening the base plate or mold clamp screws may cause cracking of the mold and subsequent leaking of molten metal.

4.8.2 Improper or careless luting (sealing) of the mold may cause leakage of the molten metal.

4.8.3 *Avoid all contact with moisture. Molten steel and slag can cause serious explosions when contacted by any form of moisture.*

4.8.4 Personnel must wear railroad approved safety glasses at all times.

4.8.5 Slag basin should be emptied only after the slag has completely solidified. Solid slag should be disposed of in such a manner as not to pose any hazard to operating personnel.

5. Flash Welding (FW) (Electric Flash Butt Welding) of Rail

5.1 General Process Description

5.1.1 The automated resistance welding process (see Figures A6 and A7) heats and prepares the rail ends, provides a nonoxidizing environment, and forges the rail ends into a welded joint. Critical flash butt welding parameters are shown in Appendix C.

5.1.2 The process and related equipment may contain the following operations: preparation, preheating, flashing, forging, shearing, postweld heat treatment, and finishing.

5.1.3 Chapter 4 Part 2 of The American Railway Engineering Association (AREA) Manual [4-2-6 *Specification for Fabrication of Continuous Welded Rail*] provides minimum specifications for rail welding.

5.2 Rail Preparation

5.2.1 Rail ends should be free of rust, dirt, grease, or other foreign material that would impede the start of a low-voltage electric arc.

5.2.2 Electrode contact points should be free from rust or slag that might provide added resistance to the flow of high electric current and thus cause electrode burns on the rail.

5.2.3 An electrode burn on welded rails shall be defined as follows:

(1) Any electrode contact areas which have transformed to martensite

(2) Any electrode contact areas which have been displaced during welding

(3) Any electrode contact areas which contain transferred electrode copper

5.2.4 Rails should be presented to the stations of the welding plant in a consistent manner to enhance production and performance.

5.2.5 Rails should be grouped by length, composition, type, and wear to minimize adjustments required by operating personnel.

5.3 Rail Welding

5.3.1 Railroad rails shall be electric flash butt welded using only the following:

(1) A previously qualified welding procedure.

(2) Welding equipment certified as being able to consistently reproduce the required welding program.

(3) A qualified operator able to set up the welding program dictated by 5.3.1, calibrate the monitoring equipment, and maintain the machine.

(4) Acceptable sample welds shall qualify the welding procedure, the welding equipment, and the welding operator simultaneously.

5.3.2 Sample welds made in accordance with 5.3.1 should be subjected to the following tests and meet the minimum requirements as specified in Table 2:

(1) Slow bend tests to determine load and deflection (see Appendix D)

(2) Hardness tests to evaluate resistance to wear and deformation (see Figure D4)

(3) Macroetch tests to determine metallurgical soundness, forging patterns, and heat-affected zone (see Figure D3)

(4) Rolling load test to determine fatigue life (see Appendix D) at the customer's option

(5) Microetch examination to evaluate metallurgical quality at the customer's option

5.3.3 Test samples and the results of testing should be evaluated by qualified personnel designated by the

Table 2
Minimum Performance Specifications for New Electric Flash Butt and Thermite Welded Rail

	Slow Bend Testing		
Material	Modulus of Rupture[1]	Minimum Deflection (Electric Flash Butt Welding)	Minimum Deflection (Thermite Welding)
Soft Carbon Rail	100,000 psi (690 MPa)	1.5 in. (38mm)	1.0 in. (25 mm)
Standard Carbon Rail	135,000 psi (930 MPa)	1.5 in. (38mm)	1.0 in. (25 mm)
Premium Steel Rail	135,000 psi (930 MPa)	0.75 in. (19mm)	0.6 in. (15 mm)

	Optional Rolling Load Test	
Material	Loads	Cycles
All rails	See Table D1	2,000,000

	Hardness Survey[2]
Materials	Deviation from Parent Material
Standard Carbon Rail	+40 BHN –60 BHN to maximum of 410 BHN
Premium Steel Rail	+60 BHN –80 BHN to maximum of 415 BHN

	Macroetch (Electric Flash Butt Welded Rail Only)
Structures	Specification
Grain turn-out angle	35° to 75°
Parallel Heat-Affected Zone	1/4" maximum deviation

Notes:

1. $\frac{(9 \times \text{Load})}{\text{Section Modulus}} = \text{Modulus of Rupture}$

2. Measurements may be taken in Rockwell Hardness Numbers and converted to Brinell Hardness Numbers.

engineer in charge and experienced in the flash welding of rail before production welds are made.

5.3.4 Production operations should be monitored by an inspector to ensure compliance with specifications.

5.3.5 Weld parameters for each weld shall be recorded.

5.3.5.1 Recorders should be calibrated daily before use.

5.3.5.2 These permanent records shall be retained by the verification inspector or operating authority.

5.3.5.3 Records shall be compared with those certified by qualified personnel during qualification testing.

5.4 Finishing Operations

5.4.1 Excess weld material shall be removed.

5.4.2 Finished contour should be as specified by qualified personnel. In the absence of specific instructions, the requirements of AREA Specifications 4-2-6.1 should apply.

5.5 Nondestructive Testing

5.5.1 Final inspection of the welded rail shall be done at the last station of the welding plant prior to acceptance for transportation and installation (see Figure A7).

5.5.2 Geometry Inspection (Rail Weld Alignment). Rail weld geometry shall be checked with a straight edge and taper gauge in accordance with the requirements of AREA 4-2-6.2 or those selected by the operating authority. If alignment adjustments are required they shall be performed at a temperature below 900°F (482°C).

5.5.3 Magnetic particle inspection shall be used to inspect for surface defects such as piped rail, shear tears, craters pushed to the surface, and for the presence of free cementite. Testing shall be in accordance with ASTM E709, *Practice for Magnetic Particle Inspection*, and performed below 800°F (427°C). Cementite will not be indicated at a temperature below 400°F (205°C). Results

of the inspection shall meet or exceed the requirements of the operating railroad.

5.5.4 Ultrasonic Inspection. Ultrasonic inspection is best suited to inspection of flash butt welded rail installed in the track. It may be used, with reservations, in the production line. Results of the inspection shall meet or exceed the requirements of the operating railroad.

5.5.5 Radiography. Radiography is not recommended for the inspection of flash butt welded rail. Defects are very difficult to detect and interpret.

5.5.6 Table 2 lists a number of tests that may be used to evaluate the quality of maintenance welds.

5.6 Rail Storage

5.6.1 A point man should safely guide and monitor transfer of the welded rail string from the production line into, or onto, the storage rack, ground storage, or continuous welded rail (CWR) train.

5.6.2 Care should be exercised to prevent kinking the rail string.

5.6.3 Rail strings should be supported at 25 to 35 ft (8 to 11 m) intervals to prevent bending during handling and storage.

6. Procedure Qualification—Arc Welding Processes

6.1 There are no prequalified procedures for railroad track maintenance welding.

6.2 Each operating authority or railroad service company should develop a welding procedure for each specific application, base metal, and process combination in accordance with the general guidelines of this document.

6.3 Qualified welding procedures may be utilized at any location within the individual authority.

6.4 Welding procedure should be documented on a form, or forms, equivalent to Form 1 in the back of this document. All tests may not be required, but selected tests shall be performed as agreed between the contractor and operating authority.

7. Welder, Welding Operator, and Track Welder Qualification—Arc Welding Processes

7.1 Any welder, welding operator, or track welder who successfully performed the procedure qualification should be qualified to perform the same operations in production.

7.2 All other welders, welding operators, or track welders should prepare one or more workmanship samples to verify performance for the welding supervisor. The type, size, and number of the workmanship samples may be determined by qualified personnel designated by the engineer in charge.

7.3 Results of the evaluation of the workmanship samples should be recorded and made part of the permanent record of the welder, welding operator, or track welder.

7.4 Qualification should be documented in accordance with Form 2 in the back of this document, or equivalent. All items may not be required but selected information shall be provided as agreed between the contractor and operating authority.

Annex A
Welding Processes

(This Annex is not a part of ANSI/AWS D15.2-94, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is supplied for information only.)

A1. Arc Welding

A1.1 Shielded Metal Arc Welding (SMAW) (Stick Welding)

A1.1.1 An arc welding process with an arc between a covered electrode and the weld pool. The process is used with shielding from the decomposition of the electrode covering, without the application of pressure, and with filler metal from the electrode.

A1.1.2 See Figure A1 for a schematic of the process.

A1.2 Gas Metal Arc Welding (GMAW)

A1.2.1 An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an externally supplied gas and without the application of pressure.

A1.2.2 See Figure A2 for a schematic of the process.

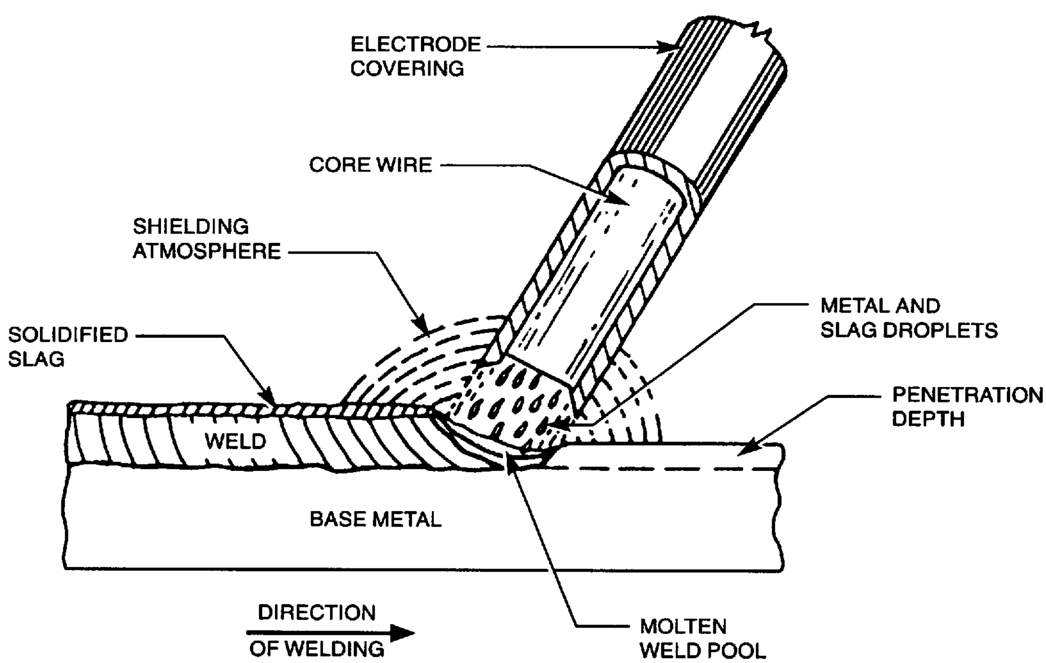


Figure A1—Shielded Metal Arc Welding (SMAW)

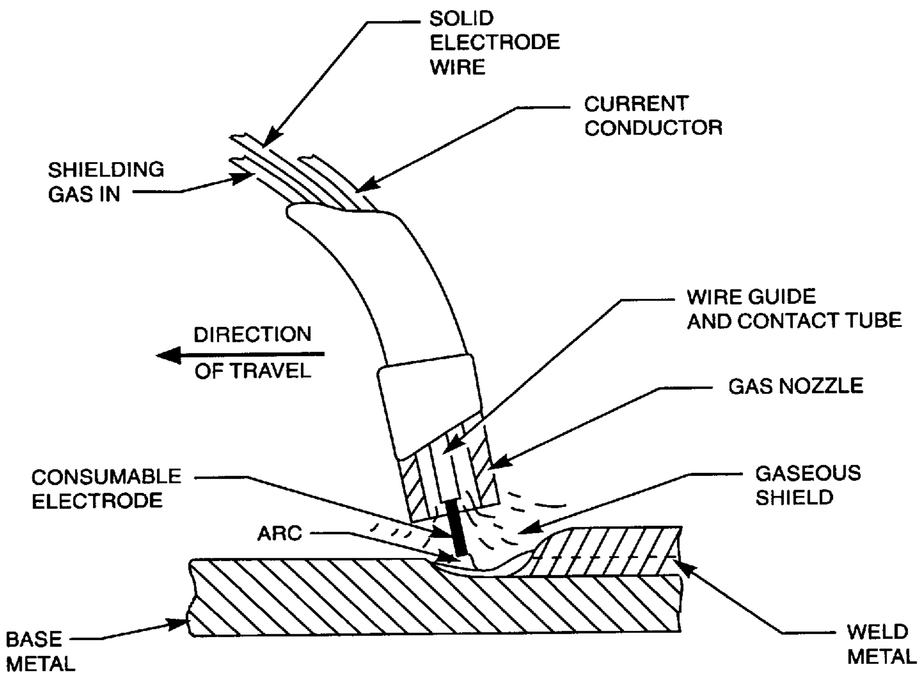


Figure A2—Gas Metal Arc Welding (GMAW)

A1.3 Flux Cored Arc Welding (FCAW)

A1.3.1 An arc welding process that uses an arc between a continuous filler metal and the weld pool. The process is used with a shielding gas from a flux contained within the tubular electrode, with or without additional shielding from an externally supplied gas, and without the application of pressure.

A1.3.2 See Figure A3 for a schematic of the process.

A1.4 Oxyfuel Gas Welding (OFW)

A1.4.1 A group of welding processes that produces coalescence of workpieces by heating them with an oxyfuel gas flame. The processes are used with or without the application of pressure and with or without the addition of filler metal.

A1.4.2 See Figure A4 for a schematic of the process.

A2. Thermite Welding (TW)

A2.1 A welding process that produces coalescence of metals by heating them with superheated liquid metal from a chemical reaction between a metal oxide and aluminum, with or without the application of pressure. Filler metal is obtained from the liquid metal.

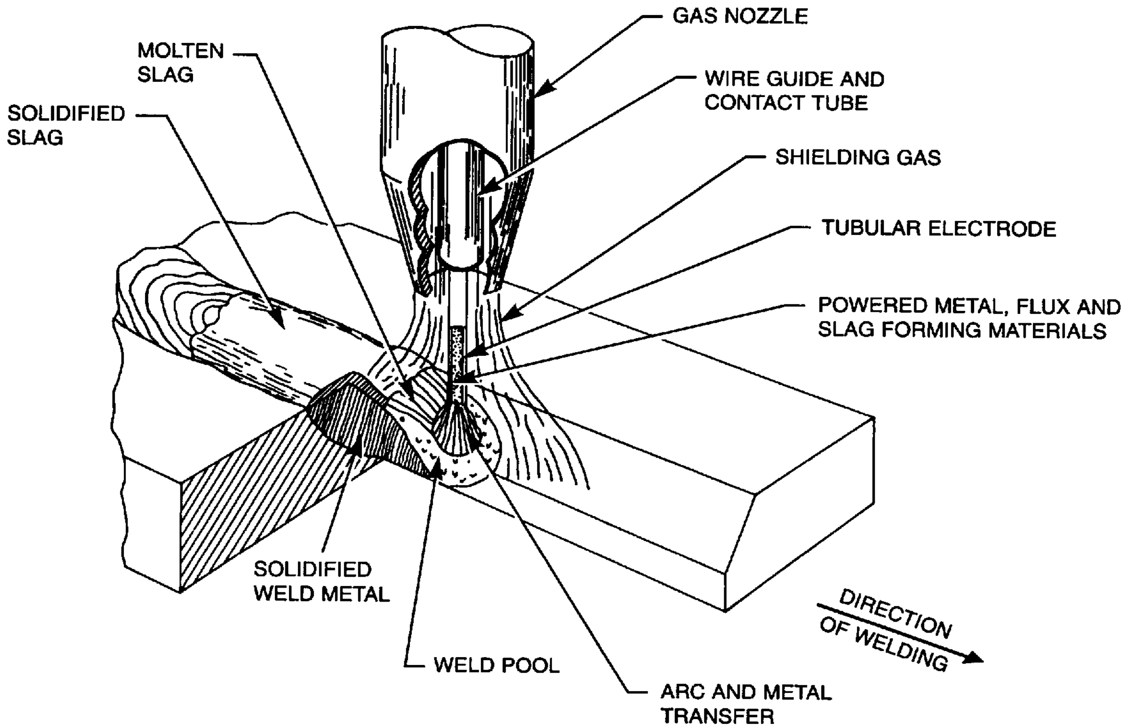
A2.2 See Figure A5 for a typical thermite installation.

A3. Flash Welding (FW) (Electric Flash Butt Welding)

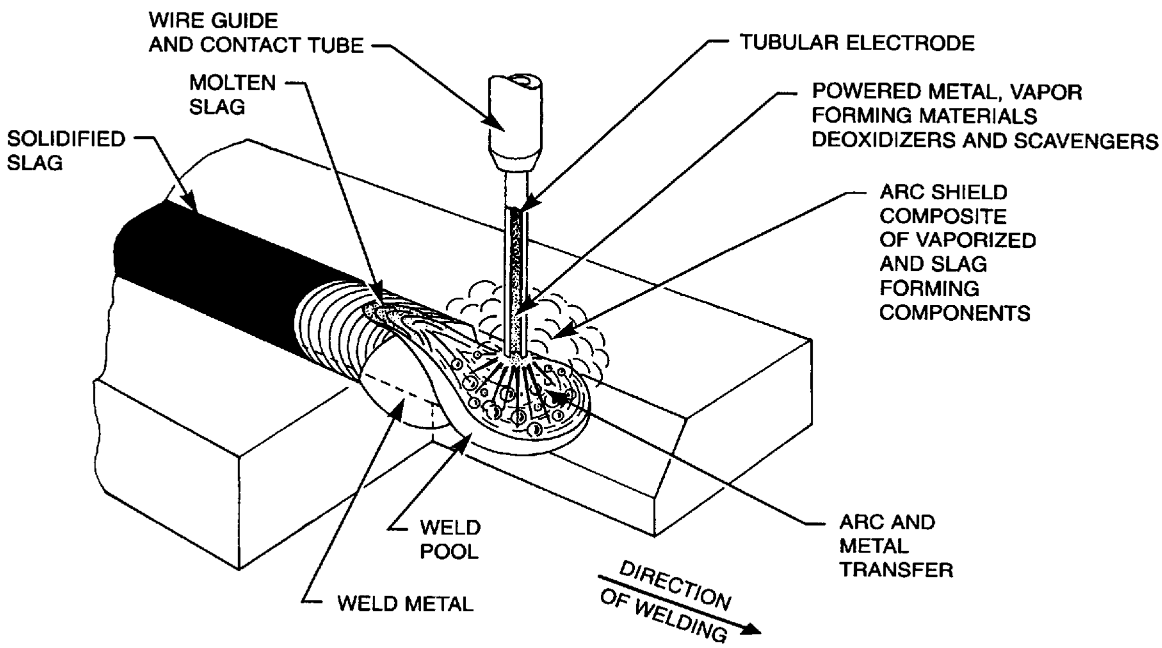
A3.1 A resistance welding process that produces a weld at the faying surfaces of a butt joint by a flashing action and by the application of pressure after heating is substantially completed. The flashing action, caused by very high current densities at small contact points between the workpieces, forcibly expels the material from the joint as the workpieces are slowly moved together. The weld is completed by a rapid upsetting of the workpieces.

A3.2 In the welding of continuous rail, the flash welding machine (Figure A6) is only one station in the production cycle (Figure A7).

A4. For further discussions of the arc welding processes refer to Volume 2, Eighth Edition, *Welding Handbook*.

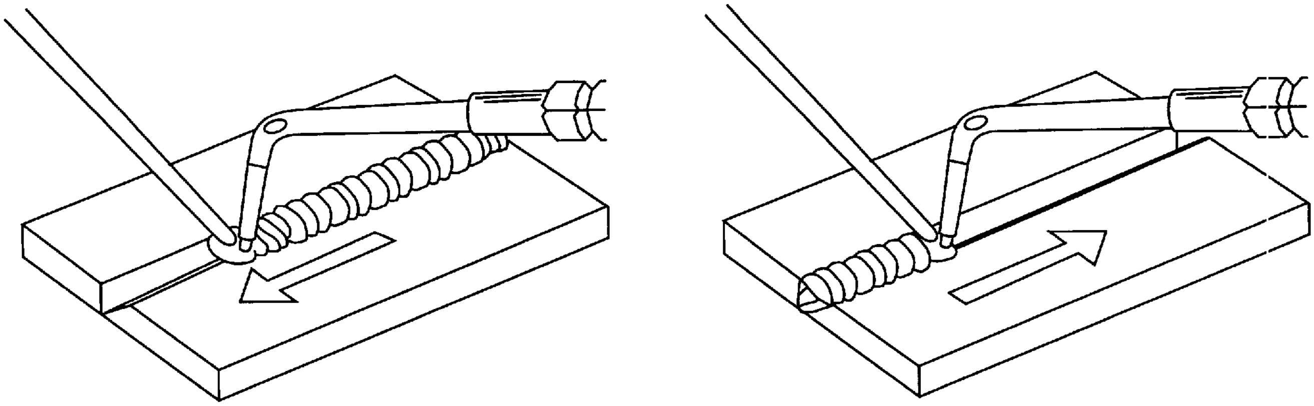


(A) GAS SHIELDED



(B) SELF SHIELDED

Figure A3—Flux Cored Arc Welding (FCAW)



(A) FOREHAND TECHNIQUE –
FILLER ROD PRECEDES THE FLAME

(B) BACKHAND TECHNIQUE –
FLAME PRECEDES THE FILLER ROD

Figure A4—Oxyfuel Gas Welding (OFW)

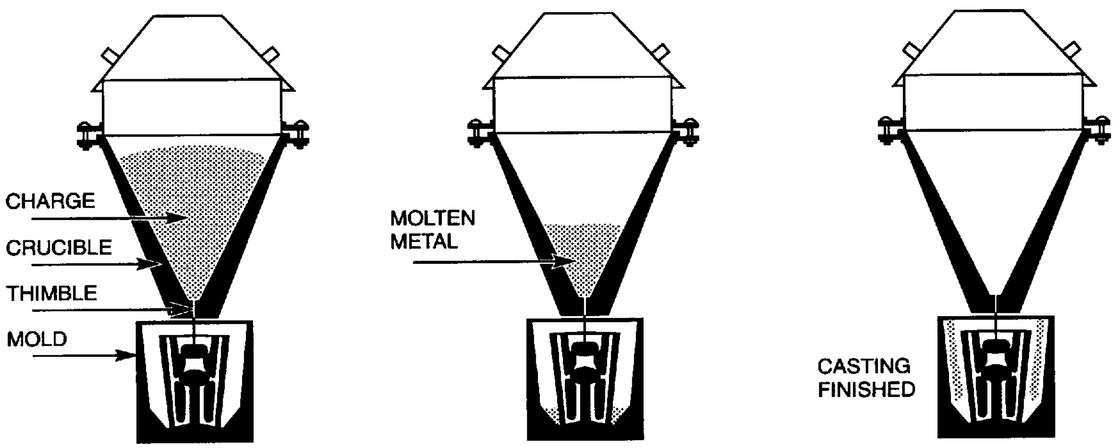


Figure A5—Section Through a Thermite Mold and Crucible

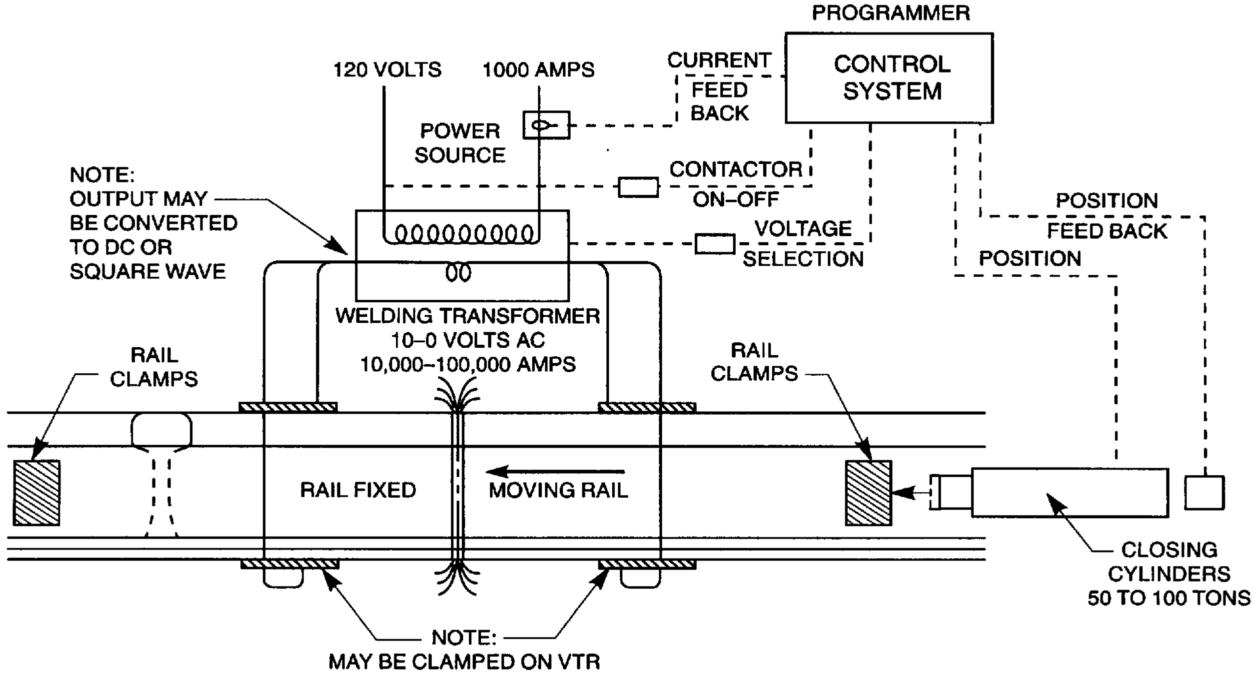


Figure A6—Automatic Hydraulically Operated Flash Welding Maching with Horizontal Clamping

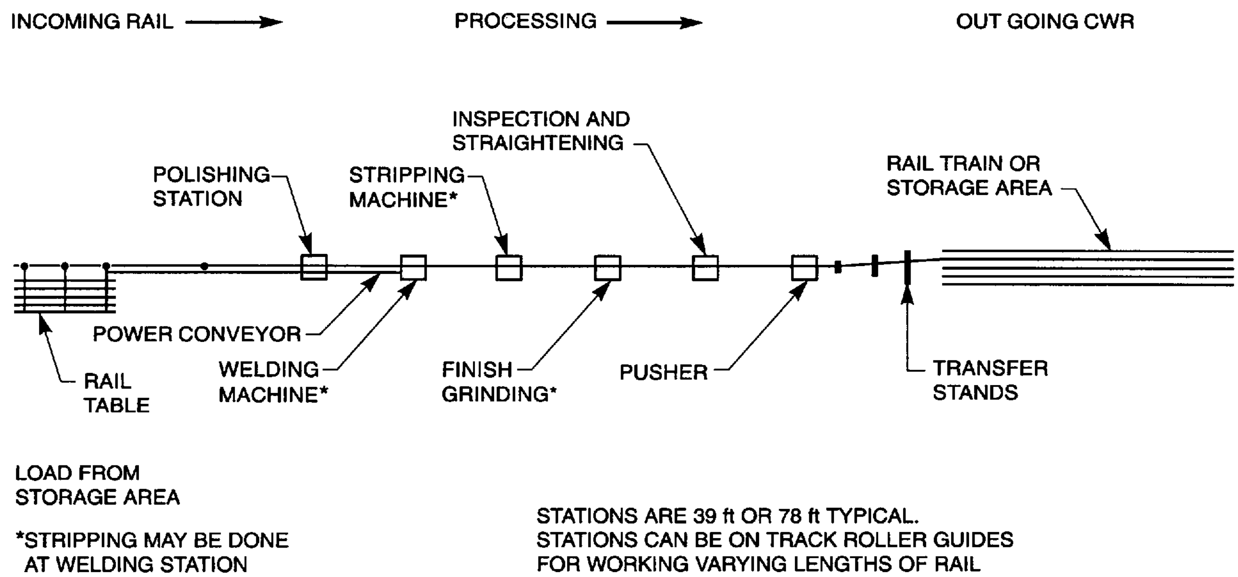


Figure A7—Rail Welding Production Line

Annex B
Welding of Austenitic Manganese Steel

(This Annex is not a part of ANSI/AWS D15.2-94, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is supplied for information only.)

B1. Introduction

B1.1 Austenitic manganese steel is an extremely tough, nonmagnetic alloy with properties uniquely different from those of most commonly used structural and wear resistant steels. It is the preferred material for a number of trackwork components, with frogs and crossings the most important. It has high strength and durability and resists failure under impact and heavy loading. Its capacity for work hardening is a major asset; the surface of the part hardens under impact, undergoing some deformation, while the underlying body retains its original toughness. The propagation rate of any cracks that may be initiated is extremely slow. Metal-to-metal wear resistance is excellent. Resistance to abrasive wear is good, compared to that of carbon steel and low alloy steels.

B1.2 Austenitic manganese steel is available as castings, which comprise the most tonnage. Rolled plate, bars and wire, as well as electrodes for welding in various forms also are available.

B2. Composition

A number of modifications of the original Hadfield composition are produced commercially as castings; the ASTM A128 *Standard Specification for Steel Castings, Austenitic Manganese* lists ten grades. For trackwork castings the American Railway Engineering Association (AREA) requires production in conformance with ASTM A128, *Standard Specification for Steel Castings, Austenitic Manganese*, except that the chemical requirements are modified slightly as follows:

Carbon	1.00/1.30%
Manganese	12.00% Min
Silicon	1.00% Max
Phosphorus	0.07% Max

Some lower carbon steel castings alloyed with molybdenum are used in special applications.

For many purposes, the optimum carbon content is about 1.15 percent, considering foundry and heat treating problems, casting properties, and economy. The high-manganese content plays a vital role in stabilizing the austenite by retarding its transformation to other structures. Silicon is present mainly for deoxidization purposes. Phosphorus is restricted because of its tendency to promote hot cracking, both in the foundry and in subsequent welding operations.

Composition of filler metals deposited by austenitic manganese electrodes differ from casting analyses to provide the desired austenitic structure with weld cooling rates. Carbon commonly is somewhat reduced and additional alloying elements are added to maintain acceptable mechanical properties. Nickel, molybdenum, chromium, and vanadium, alone or in combinations, are used as added alloying elements in austenitic manganese steel welding electrodes.

B3. Basic Metallurgy

B3.1 At high temperatures, the structure of steel is essentially austenitic; most carbon steels and alloy steels transform from the austenitic structure to other structures as the metal cools. Large manganese additions effectively suppress the transformation of austenite, so that with sufficiently fast cooling an austenitic structure is retained at room temperature.

B3.2 Before heat treatment, manganese steel castings are relatively brittle, as slow cooling in the molds does not provide a fully austenitic structure. Heat treatment involves heating to the appropriate austenitizing tempera-

ture, usually in the 1850 to 1950°F (1010 to 1065°C) range, holding until the sections are fully austenitic and all carbides dissolved, and quenching in cold, agitated water.

B3.3 The microstructure of properly quenched manganese steel consists of distinct grains of austenite. Excessive carbides in the grain boundaries or in other manifestations are undesirable, as the mechanical properties of the steel will be lower than normal. Either inadequate austenitizing or too slow cooling from the austenitizing temperature can result in excessive carbides.

B3.4 The reheating of manganese steels can also cause carbide precipitation and impaired properties, with the degree of embrittlement dependent upon both the exposure time and temperature. This is the reason for welding procedures which avoid prolonged overheating of weldments.

B4. Physical Properties

B4.1 Magnetic Characteristics. The untransformed austenite of manganese steels is virtually nonmagnetic. The surface skin of castings may be somewhat magnetic; this is not detrimental in castings for wear-resistant service.

B4.2 Thermal Conductivity. The thermal conductivity of manganese steels is about 25 percent that of mild steel at room temperature, and continues to be substantially less at higher temperatures. This contributes to localized heat buildup during welding.

B4.3 Thermal Expansion. The thermal expansion of manganese steels is similar to that of most other austenitic materials and greater than that of ferritic steels. The change in length on heating is about 1-1/2 times that of carbon steel.

B5. Mechanical Properties

B5.1 Tensile and Yield Strengths. The properties of cast manganese steels vary considerably with composition, section thickness, and grain size. For the grade used for trackwork, typical properties are as follows:

Tensile strength	100 000–145 000 psi (690–1000 MPa)
Yield strength	50 000–57 000 psi (345–393 MPa)
Elongation, %	30–65%
Hardness	185–210 Brinell

B5.2 Impact Characteristics. Austenitic manganese steels have excellent impact properties, as measured by Charpy V-notch impact tests. For unalloyed manganese steels of the type used for trackwork, the impact strength is about 90 to 100 ft-lb (122-136J) at 75°F (24°C) and about 45 to 65 ft-lb (61-88J) at -100°F (–73°C). These values confirm the outstanding toughness manganese steels provide in service under extremely cold conditions.

B5.3 Work Hardening Characteristics. In comparing manganese steels to other steels, their very high capacity for work hardening must be considered. The hardness can increase from about 200 Brinell to a maximum of about 550 Brinell, with an accompanying increase in yield strength. Work hardening is produced by deformation and allowance must be made for the metal flow that occurs, either in design or by maintenance practices. For trackwork buildup, electrodes which provide deposits considerably higher in yield strength than cast manganese steels can be used to minimize but not eliminate deformation in service.

B6. Welding Electrodes

B6.1 Austenitic Manganese Electrodes. Electrodes may be in the form of solid wire, tubular wire with internal alloying and fluxing ingredients, cut-to-length tubular electrodes with or without external covering, and covered electrodes with part or all of the alloys in the covering.

Austenitic manganese steel electrodes are available as continuous wire and as bare or covered electrodes for manual welding.

In the past, drawn, solid manganese steel electrodes, bare or with a light coating, were used extensively for the buildup of worn castings. They had the advantage of fast burn-off, high efficiency, and high bead buildup. On the adverse side, usability was relatively poor, requiring highly skilled welders to produce deposits free from porosity, inclusions, and cracking. As the electrodes were produced from large heats of steel the number of compositions available was very limited and phosphorus levels depended upon the capability of the producing mill.

B6.2 Composite Electrodes. Bare manganese electrodes largely have been replaced by composite electrodes with alloys in the covering. Weldability is good and sound welds are obtained readily with normal procedures. Phosphorus content can be held consistently below 0.030 percent, greatly lessening the likelihood of weld cracking. Several compositions are available, alloyed with additions of nickel, molybdenum, chromium, and vanadium, alone or in combinations. A range of deposit properties is available, providing choices for different application requirements. For example, yield strength matching that of the base metal might be specified for fabrication or crack repair. Higher yield strength with better resistance to deformation might be specified for buildup of a worn railway crossing.

B6.3 Tubular Electrodes. Bare tubular wire electrodes, used for track maintenance, are designed to weld without external shielding gas. As for composite electrodes, the phosphorus content is kept low. The resultant welds have excellent mechanical properties and resistance to cracking. A number of variations in composition are available.

B6.4 Other Austenitic Electrodes. In addition to austenitic manganese steel electrodes, other austenitic compositions can be used for welding austenitic manganese steel. For wear applications, the most commonly used are relatively high-carbon chromium-nickel-manganese and chromium-manganese alloys. These alloys often are more costly than austenitic manganese steel electrodes. Performance advantages in certain applications may more than offset differences in initial cost.

B7. Welding Procedures

Work hardened manganese steels are more susceptible to cracking when welded than unhardened metal. For that reason, work hardened metal, cracks, and other defects should be removed prior to the start of welding. Grinding, air-carbon-arc gouging, or exothermic metal removal processes should be used. Care should be taken not to overheat the base metal during gouging; therefore, oxyfuel gas cutting is not recommended due to excessive heat input.

Under normal conditions, preheat is not used. In extremely cold weather, the parts may be warmed to approximately 70°F (21°C). Welding procedures are intended to prevent the buildup of excessive heat in localized areas, and the consequent embrittlement of the base metal under the weld. Current, voltage, and travel speed should be such as to deposit relatively narrow rounded beads; large or very wide beads should be avoided. Skip welding should be used to minimize heat buildup, and can be effectively utilized on most worn castings. The temperature approximately 1 in. (25 mm) from the weld should be maintained below 500°F (260°C). As a rule of thumb, it should be possible to touch the base metal six inches from the weld without discomfort.

Annex C
Typical Electric Flash Butt Welding Parameters

(This Annex is not a part of ANSI/AWS D15.2-94, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is supplied for information only.)

C1. Primary welding current furnished to welding transformer shall be recorded. The following must be observed:

C1.1 Total electrical energy (heat input) should match the standard certified record.

C1.2 Loss of current flow for more than 3 cycles (50 ms) during the last half inch (13 mm) of burn-off flashing before upset stroke shall be cause for weld rejection and cut out.

C1.3 Current flow must continue at least one half second after upset stroke starts or weld shall be rejected.

C2. Platen position (relationship of fixed and moving rail) shall be recorded. The following must be observed:

C2.1 Total rail consumed to make weld should match standard certified record with tolerances of +1/2 in. (12.7 mm) and –1/8 in. (3.2 mm).

C2.2 Upset stroke should consume (forge) the same, or greater, amount of rail as consumed in the standard. Velocity, or upstroke, should be consistent with the standard certified record.

C2.3 The hold time should be consistent with the standard to prevent hot tears and hold alignment.

C3. Force between rail ends, as measured through welding cylinders, is an optional recording. The following can be determined:

C3.1 The total force to make the weld should approximately match the standard.

C3.2 A minimum force, as determined by qualified personnel, should be executed between rail ends during the upset stroke.

C4. Recordings should be reported on the chart, beginning and end of each shift, and the heat numbers of all rails noted. Also, environmental factors such as temperature, wind, weather, etc., should be recorded on beginning of each chart. Operator should sign chart at end of day or chart shift.

Annex D
AREA Tests for Continuous Welded Rail

(This Annex is not a part of ANSI/AWS D15.2-94, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is supplied for information only.)

D1. Rolling Load Test

D1.1 The rolling load test basically is a full-scale fatigue test that produces measurable stress. Welded specimens then can be evaluated on a comparative basis.

D1.2 Test Equipment. Figure D1 shows the typical load arrangement used for a 12 in. (300 mm) stroke test machine.

D1.2.1 The weld, Figure D1, is located 2 in. (50 mm) in front of the front support providing a 10 in. (250 mm) moment arm. The wheel travels over the front support to 10 in. (250 mm) past the weld, stressing the longitudinal fibers of welded rail from 0 to maximum stress.

D1.2.2 Wheel load may be varied by adjusting the load spring in accordance with Table D1.

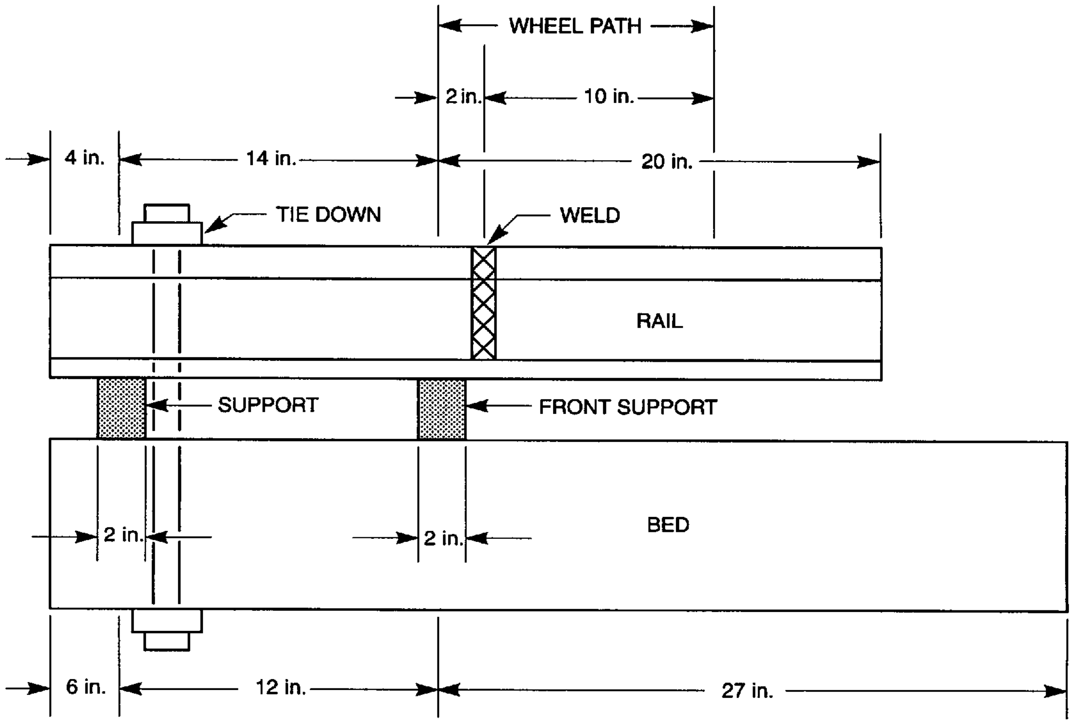
D1.2.3 Normal test is 60 cycles per minute for a total 2 million cycles or to failure, whichever occurs first.

D2. Slow Bend Test

D2.1 Welded assembly is placed head up on a four point loading fixture, Figure D2, with the base supports 48 in. (1200 mm) apart. The fixture is designed so that the one support is stationary and the other support swivels to eliminate torsional loading that might result in uneven bearing between the rail base and the support.

D2.2 Load is applied to the rail head at two loading points spaced 12 in. (300 mm) apart.

D2.3 Load is applied to the welded assembly in the center of the fixture until the assembly fractures or deflects 4 in. (100 mm), whichever comes first.



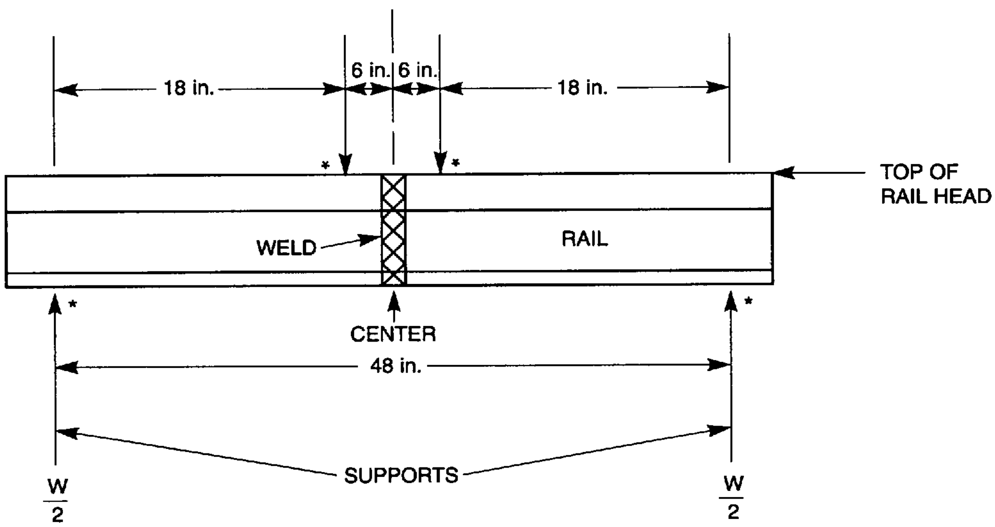
SI EQUIVALENTS

in.	mm
2	50
3	75
10	250
12	300
14	350
19	475
27	675

Figure D1—Loading Arrangement for the 12 in. Stroke Rolling Load Machine

Table D1
Wheel Loads for Rolling Load Test

Weight of Rail Section		Wheel Loads	
Pounds/yard	Kilograms/meter	Pounds	Kilograms
80	39.7	29,500	13,380
85	42.2	32,300	14,650
90	44.6	35,000	15,880
100	49.6	40,200	18,230
112	55.6	46,600	21,140
115	57.0	48,200	21,860
119	59.0	50,300	22,820
122	60.5	52,000	22,590
130	64.5	56,200	25,490
131	65.0	56,700	25,720
132	65.5	57,300	25,990
133	66.0	58,700	26,630
136	67.5	59,400	26,940
140	69.4	61,300	27,810



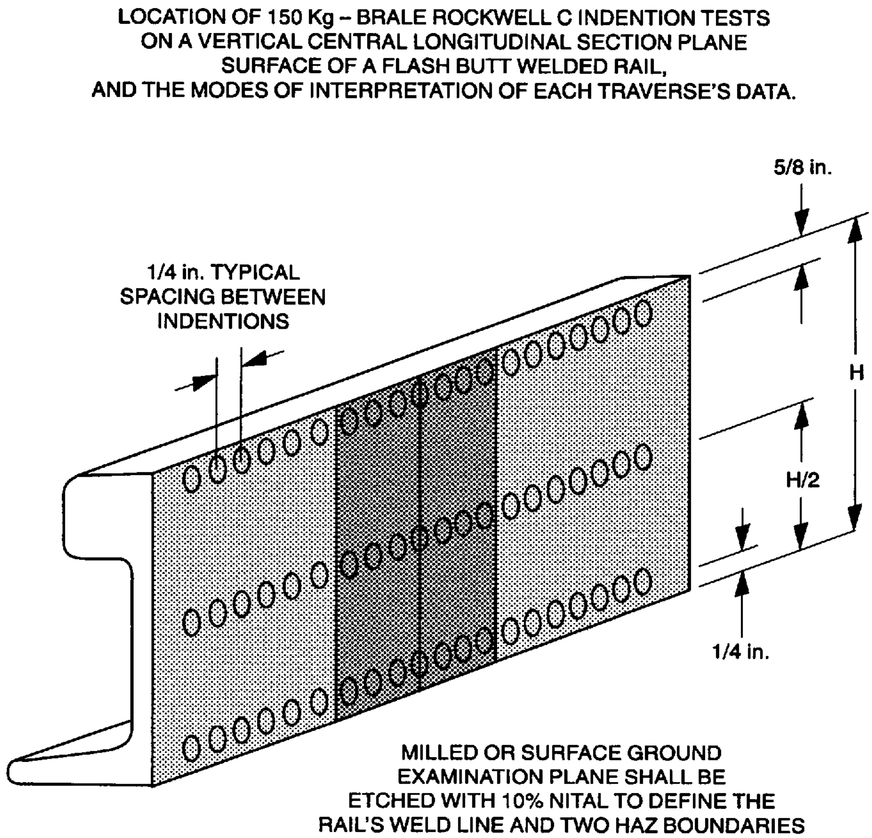
$$\frac{9W}{\text{SECTION MODULUS OF THE RAIL BASE}} = \text{MODULUS OF RUPTURE}$$

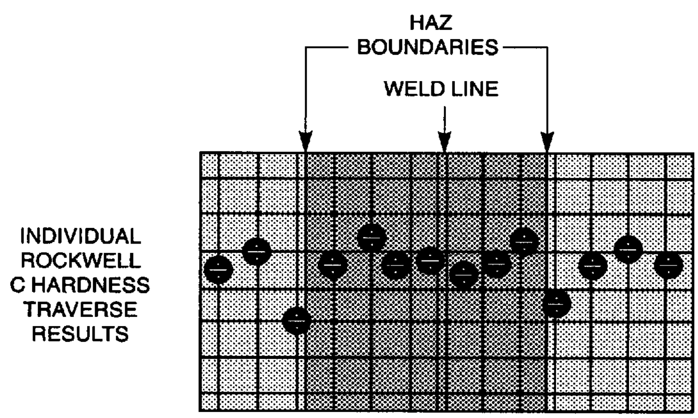
* RECOMMENDED PIN DIAMETER SHALL BE 2 TO 3 in. (51 TO 76 mm)

SI EQUIVALENTS

in.	mm
6	150
18	450
48	1200

Figure D2—Loading Arrangement for the Slow Bend Test and Formula for Deriving the Modulus of Rupture

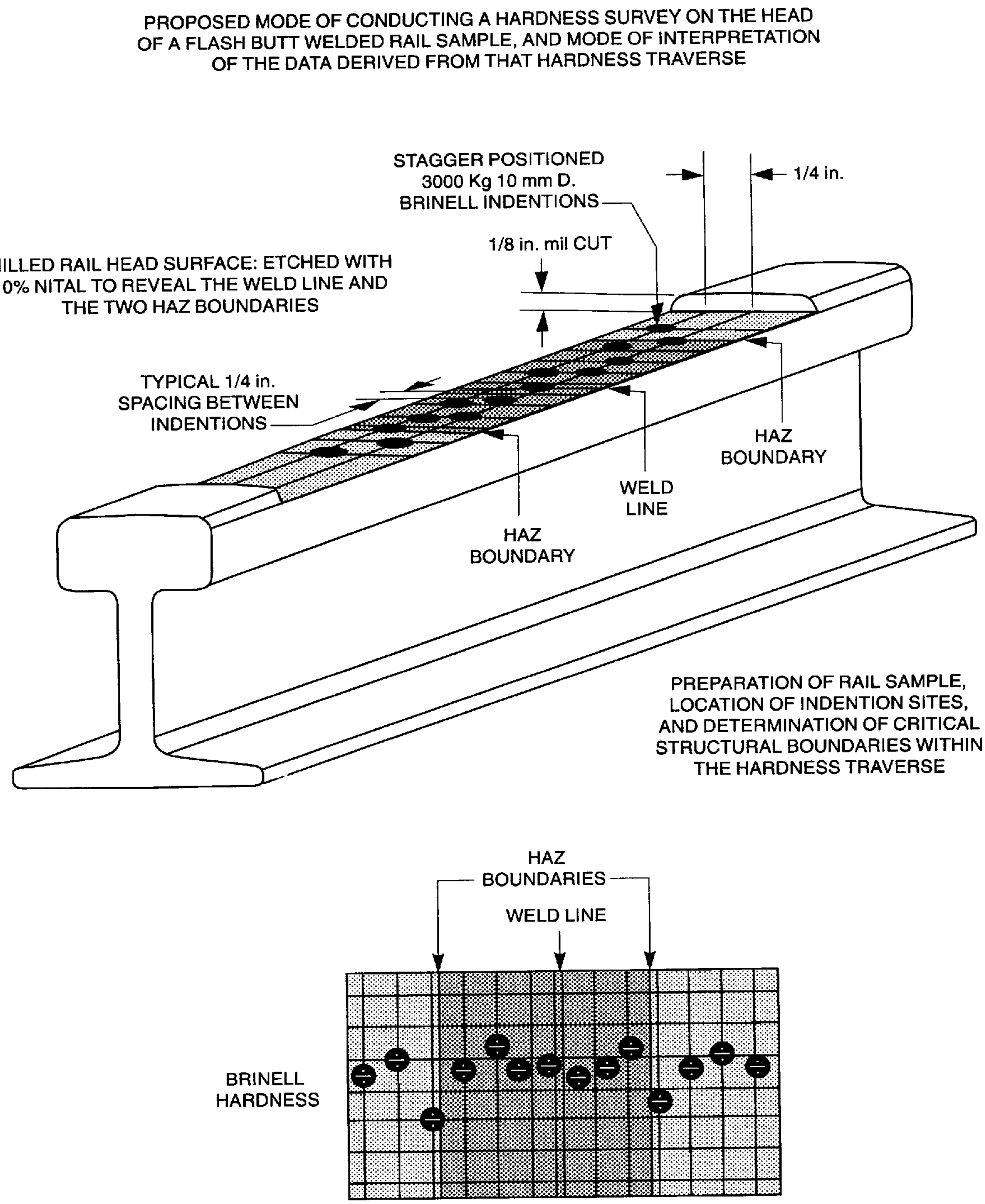




SI EQUIVALENTS

in.	mm
1/4	6.4
5/8	16

Figure D3—Layout of Transverse Hardness Survey



SI EQUIVALENTS

in.	mm
1/8	3.2
1/4	6.4

Figure D4—Layout of Hardness Survey on Rail Head

Annex E
Safe Practices

(This Annex is not a part of ANSI/AWS D15.2-94, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is supplied for information only.)

These recommended practices may involve hazardous materials, operations, and equipment. The document does not purport to address all of the safety problems associated with their use. It is the responsibility of the user to establish appropriate safety and health practices. The user should determine any regulatory limits prior to use.

E1. Fumes and Gases

Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management, personnel, and welders alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the filler metal and base metal, welding process, current level, arc length, and other factors.

More detailed information on fumes and gases produced by the various welding processes may be found in the following:

(1) The permissible exposure limits required by OSHA can be found in CFR Title 29, Chapter XVII Part 1910. The OSHA *General Industry Standards* are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

(2) Material Safety Data Sheets (MSDS) are available upon request from suppliers for product safety and health information.

(3) The results of an AWS-funded study are available in a report entitled, *Fumes and Gases in the Welding Environment*, available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

E2. Electrical Hazards

Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

The correct cable size should be used since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks.

Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity. To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber soled shoes, or stand on a dry board or insulated platform.

Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used.

Open circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being

used, the open circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned **OFF**. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

Recognized safety standards such as ANSI/ASC Z49.1, *Safety in Welding and Cutting*, and the National Electrical Code and NFPA No. 70, available from National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, should be followed.

E3. Noise

Excessive noise is a known health hazard. Exposure to excessive noise can cause a loss of hearing. This loss of hearing can be either full or partial, and temporary or permanent. In welding, cutting, and allied operations, noise may result from the process, the power source, or other equipment. Air-carbon arc and plasma arc are examples of processes, which are frequently noisy. Engines of engine-driven generators may also be quite noisy.

Excessive noise adversely affects hearing capability. This adverse effect in hearing capability may be a temporary threshold shift from which the ears may recover if removed from the noise source. However, if a person is exposed to this same noise level for a longer time, then the loss of hearing may become permanent. The time required to develop permanent hearing loss depends upon factors such as individual susceptibility, noise level, and exposure duration. In addition, there is evidence that excessive noise affects other bodily functions and behavior.

A direct method to protect against excessive noise is to reduce the intensity of the source. Another method is to shield the source, but this has limitations. The acoustical characteristics of a room will also effect the level of noise. When engineering control methods fail to reduce the noise, personal protective devices such as ear muffs or ear plugs may be employed. Generally, these devices are only accepted when engineering controls are not fully effective.

The permissible noise exposure limits can be found in CFR Title 29, Chapter XVII, Part 1910. This is available from the U.S. Government Printing Office, Washington, DC 20402. Additional information may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists, 6500 Glenway Avenue, Bldg. D-5, Cincinnati, OH 45211.

A recommended method for measuring noise emitted by arc welding processes may be found in the latest edition of AWS F6.1, *Method for Sound Level Measurement of Manual Arc Welding and Cutting Processes*, published by American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

E4. Burn Protection

Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn in combination with goggles or equivalent to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flame. Aprons, cape-sleeves, leggings, and shoulder covers with bibs designed for welding service should be used.

Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph.

Before leaving a work area, hot work pieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load. Disconnection under load produces arcing of the contacts and may cause burns or shock, or both. *(Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.)*

The following sources are for more detailed information on personal protection:

(1) ANSI/ASC Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(2) Code of Federal Regulations, Title 29 Labor, Chapter XVII, Part 1910, *OSHA General Industry Standards* available from the U.S. Government Printing Office, Washington, DC 20402.

(3) ANSI/ASC Z41.1, *Safety-Toe Footwear*, American National Standards Institute, 1430 Broadway, New York, NY 10018.

E5. Radiation

E5.1 Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

Radiant energy may be ionizing (such as X-rays), or non-ionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, depending on the radiant energy's wavelength and intensity, if excessive exposure occurs.

E5.1.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

E5.1.2 Non-Ionizing Radiation. The intensity and wavelengths of non-ionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base material.

E5.2 Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of non-ionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by non-ionizing radiant energy from welding include the following measures:

E5.2.1 Welding arcs should not be viewed except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute, 1430 Broadway, New York, NY 10018. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect a passerby from incidental exposure.

E5.2.2 Exposed skin should be protected with adequate gloves and clothing as specified in ANSI/ASC Z49.1, *Safety in Welding and Cutting*, published by American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

E5.2.3 Reflections from welding arcs should be avoided, and all personnel should be protected from intense reflections. *(Note: Paints using pigments of substantially zinc oxide or titanium dioxide have a lower reflectance for ultraviolet radiation.)*

E5.2.4 Screens, curtains, or adequate distance from aisles, walkways, etc., should be used to avoid exposing passersby to welding operations.

E5.2.5 Safety glasses with UV protective side shields have been shown to provide some beneficial protection from ultraviolet radiation produced by welding arcs.

Ionizing radiation information sources include:

(1) AWS F2.1-78, *Recommended Safe Practices for Electron Beam Welding and Cutting*, available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(2) Manufacturer's product information literature.

Non-ionizing radiation information sources include:

(1) J. F. Hinrichs, "Project committee on radiation-summary report." *Welding Journal*, January 1978.

(2) Non-Ionizing Radiation Protection Special Study No. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*, available from the National Technical Information Service, Springfield, VA 33161. ADA-033768.

(3) Non-Ionizing Radiation Protection Special Study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs*, available from the National Technical Information Service, Springfield, VA 22161. ADA-043023.

(4) C. E. Moss and W. E. Murray, Optical Radiation Levels Produced in Gas Welding, Torch Brazing, and Oxygen Cutting, *Welding Journal*, September 1979.

(5) Optical Radiation Levels Produced by Air-Carbon Arc Cutting Processes, *Welding Journal*, March 1980.

(6) Z136.1, *Safe Use of Lasers*, published by American National Standards Institute, 1430 Broadway, New York, NY 10018.

(7) ANSI/ASC Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(8) ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute, 1430 Broadway, New York, NY 10018.

(9) C. E. Moss, Optical Radiation Transmission Levels Through Transparent Welding Curtains, *Welding Journal*, March 1979.

Typical Welding Procedure Qualification Test Record

PROCEDURE SPECIFICATION

Base Material Description________
Welding Process________
Manual / Semi-Automatic________
Position of Welding________
Filler Metal Description________
Filler Metal Chemistry________
Filler Metal AWS Classification________
Single or Multiple Pass________
Max/Min Base Metal Temperature________
Preheat Temperature________
Interpass Temperature________
Post Heat Temperature________
Welding Current________
Welding Voltage________
Welders Name________

VISUAL INSPECTION OF WELD

Appearance________
Undercut________
Porosity________
Foriegn Material Inclusion________

HARDNESS GRADIENTS

Base Metal Hardness________
Filler Metal Hardness________
HAZ Metal Hardness________

RADIOGRAPHIC-ULTRASONIC EXAMINATION

RT Report No.________
UT Report No.________

METALLOGRAPHY EXAMINATION

Macroetch Size 1.________2.________
Microetch detail________

All Weld Metal Strength Details

Tensile Strength (PSI)________
Yield Point Strength (PSI)________
Elongation in 2 in., %________
Reduction in Area, %________

WELDING PROCEDURE

Pass No.	Electrode Size	Welding Current Amperes / Volts	Bead Size	Max Bead Length	Speed of Travel	WELD DETAIL

We the undersigned certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of AWS D15.2. (________)year

Procedure No.________
Revision No.________

Railroad or Contractor________
Authorized by________
Date________

FORM 1

Welder Qualification Test Record

Welders Name____________ Welders ID No.____________
Welding Process____________ Manual____________ Semiautomatic____________ Machine____________
Position____________
In Accordance With Procedure Specification No.____________
Material Specification____________
Rail Size____________ Switch Point Size____________ Frog Size____________
Description and Size of Other Material____________

FILLER METAL

Specification No.____________ Classification____________ F No.____________
Describe Filler Metal (if Not covered by AWS Specification)____________

Filler Metal Chemistry____________
Filler Metal Diameter____________ Is Backing Plate Used?____________

VISUAL INSPECTION

Appearance____________ Undercut____________ Porosity____________

ULTRASONIC INSPECTION

UT Method	Transducer Type	Result	Remarks

RADIOGRAPHIC INSPECTION

Film Identification	Results	Remarks

HARDNESS GRADIENT

Base Metal Hardness____________
Filler Metal Hardness____________
HAZ Hardness____________

METALLOGRAPHY EXAMINATION

Macroetch Size 1.____________ 2.____________ 3.____________ 4.____________
Macroetch Detail____________

Microetch Detail____________

Test Authorized by____________ Test Witnessed by ____________
Test No.____________

We the undersigned certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of the American Welding Society AWS D15.2. (__________) year.

FORM 2

Railroad or Contractor ____________
Date ____________

AWS Document List on Railroads	
Document Code	**Title**
D15.1	Railroad Welding Specification — Cars and Locomotives
D15.2	Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles
Additional Documents of Fundamental Subject Matter	
A1.1	Metric Practice Guide for the Welding Industry
A2.4	Standard Symbols for Welding, Brazing, and Nondestructive Examination
A3.0	Standard Welding Terms and Definitions

For ordering information, contact the Order Department, American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126. Phone: 1-800-443-9353.